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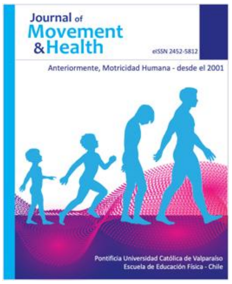

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Original article

Validation evidence of the Actigraph® GT3X inertial sensor for assessing vertical jump height

Evidencia de validación del sensor inercial Actigraph® GT3X para evaluar la altura del salto vertical

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Abstract

Objective: To evaluate the validity of the Actigraph® GT3X inertial sensor for measuring vertical jump height compared with a force plate considered the gold standard. **Methods:** This cross-sectional validation study included 42 athletes from track and field (n=16), basketball (n=12), and football (n=14), with a mean age of 22.40 ± 5.8 years. Participants performed Squat Jump (SJ) and Countermovement Jump (CMJ) tests according to the Bosco protocol on an AMTI force plate while simultaneously wearing an Actigraph® GT3X accelerometer positioned at the waist. Jump height was calculated from flight time derived from both systems. Pearson correlation coefficients, Intraclass Correlation Coefficients (ICC), and Bland-Altman agreement analyses were performed to compare measurements between devices. **Results**: High correlations were observed between the force plate and the inertial sensor across all sport modalities and jump conditions. Correlation ranged from 0.836 to 0.997. ICC (A,1) values ranged from 0.842 to 0.996, indicating excellent agreement for most comparisons. Bland-Altman analysis revealed a mean bias of 0.0076 m (95% limits of agreement: −0.0287 to 0.0438 m) for SJ and 0.0012 m (95% limits of agreement: −0.0254 to 0.0277 m) for CMJ in the combined sample. A one-sample t-test of the mean difference against zero indicated a statistically significant systematic bias for the SJ total ($p = 0.011$); no significant bias was detected for CMJ or any modality-specific comparison (all $p > 0.05$). **Conclusion:** The Actigraph® GT3X demonstrated strong validity for assessing vertical jump height in athletes, showing high correlation, excellent ICC values, and clinically acceptable agreement with the gold-standard force plate.

Keywords: vertical jump; inertial sensors; force plates; correlation and agreement; neuromuscular assessment

Resumen

Objetivo: Evaluar la validez del sensor inercial Actigraph® GT3X para medir la altura del salto vertical en comparación con una plataforma de fuerza considerada estándar de referencia. **Métodos:** Este estudio transversal de validación incluyó 42 atletas de atletismo (n=16), baloncesto (n=12) y football (n=14), con una edad media de 22,40 ± 5,8 años. Los participantes realizaron pruebas de Squat Jump (SJ) y Countermovement Jump (CMJ) siguiendo el protocolo de Bosco sobre una plataforma de fuerza AMTI mientras utilizaban simultáneamente un acelerómetro Actigraph® GT3X fijado a la cintura. La altura del salto fue calculada a partir del tiempo de vuelo obtenido por ambos sistemas. Se realizaron análisis de correlación de Pearson y concordancia de Bland-Altman para comparar las mediciones entre dispositivos. **Resultados:** Se observaron altas correlaciones entre la plataforma de fuerza y el sensor inercial en todas las modalidades deportivas y condiciones de salto. Los coeficientes de correlación de Pearson variaron entre 0,871 y 0,996 para las evaluaciones de SJ y CMJ. El análisis de Bland-Altman demostró adecuada concordancia entre los métodos, sin diferencias estadísticamente significativas en las comparaciones ($p > 0,05$). Los valores medios de altura de salto obtenidos con el acelerómetro fueron muy similares a los medidos por la plataforma de fuerza tanto en SJ como en CMJ. **Conclusión:** El Actigraph® GT3X demostró una fuerte validez para la evaluación de la altura del salto vertical en atletas, presentando alta correlación y concordancia con la plataforma de fuerza considerada estándar de referencia.

Palabras clave: salto vertical; sensores inerciales; plataformas de fuerza; correlación y concordancia; evaluación neuromuscular

Key points

- The Actigraph® GT3X inertial sensor is a valid alternative to force plates for measuring vertical jump height.
- High correlation and agreement were found for both Squat Jump and Countermovement Jump across multiple sports.
- Wearable technology provides a cost-effective and portable solution for field-based neuromuscular assessments.

Introduction

The assessment of vertical jumps plays a crucial role in analysing functional performance and detecting potential biomechanical imbalances in athletes[1]. Understanding the biomechanical characteristics of these jumps is fundamental for optimizing sports performance, promoting musculoskeletal health, and developing rehabilitation and injury prevention strategies[2]. Vertical jump tests, highlighted as effective tools, are essential in monitoring the return to sport after injuries, providing valuable information to avoid premature return and establish realistic post-injury expectations[3]. According to Kotsifaki et al.[4], performance during vertical hops is relatively equally apportioned to the hip, knee, and ankle joints, making it a comprehensive measure of lower-limb function. This balanced contribution underscores the importance of assessing vertical jump performance as an indicator of overall lower extremity power and coordination, which is critical for both athletic performance and injury prevention.

Fares et al.[5] emphasize that physical testing in sports rehabilitation is vital for evaluating recovery and making informed decisions about an athlete's potential return to sport. A comprehensive, holistic approach, including multiple testing modalities, psychosocial assessment, and a gradual return to activity, is recommended to achieve optimal outcomes and restore pre-injury athletic levels. Vertical jump tests, being objective and quantifiable, fit well within such a framework, providing crucial data points for monitoring progress and readiness.

Vertical jump scores are correlated with salivary cortisol levels, a stress marker, in elite middle- and long-distance runners. Athletes with elevated salivary cortisol levels tend to show lower CMJ scores, indicating potential performance reduction due to accumulated stress[6]. Balsalobre-Fernández et al.[6] highlighted the importance of multifactorial monitoring of training load, hormonal status, and neuromuscular performance in elite endurance athletes to prevent overtraining syndrome. Their research demonstrated significant correlations between weekly average salivary free cortisol concentrations and CMJ scores, suggesting that CMJ can serve as a non-invasive, field-based indicator of an athlete's physiological state and readiness.

Furthermore, the CMJ vertical jump is a promising tool for monitoring neuromuscular fatigue and athlete readiness, helping to prevent overtraining[7]. Watkins et al.[7] demonstrated the sensitivity of vertical jump height as a measure of neuromuscular readiness and fatigue on a daily sessional basis. They found that decrements in vertical jump height correlated with reductions in training volume, indicating its utility for coaches to proactively understand current fatigue levels and readiness for resistance training. This makes vertical jump assessment a practical and valuable tool for daily monitoring in high-performance settings.

Although force plates are considered the most accurate equipment for vertical jump assessment, their high cost and less user-friendly interface often limit accessibility. However, a method developed by Bosco, Luhtanen, and Komi in 1983 utilizes a multiple linear regression based on jump flight time to determine height more accessibly[8]. Inertial sensors, such as those from the Actigraph® brand, are tools

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typically used to track physical activity levels and sedentary profiles[9]. However, they can also be applied to measure jump flight time and thus quantify jump height[3,10]. This study aims to compare the Actigraph® GT3X accelerometer with a force plate (gold standard) for jump assessment, verifying its validity in sports and rehabilitation contexts.

Methods

Participants and sample selection

This study included 42 athletes from sports teams affiliated with the Associated Laboratories Group (GLAss) at the Federal University of Santa Maria (UFSM) in 2023. The participants' mean age was 22.40 ± 5.8 years, with a mean body mass of 82.45 ± 19.99 kg and a mean height of 1.78 ± 0.077 m. The athletes were involved in three distinct modalities: track and field (n=16), basketball (n=12), and American football (n=14). Sample selection was performed by convenience.

Inclusion criteria comprised the absence of musculoskeletal injuries in the last six months, continuous practice in the specific modality for at least six months, and the absence of vestibular disorders, given the nature of the jump tests and potential fall risks.

Ethical requirements

The research was approved by the Human Research Ethics Committee of the Federal University of Santa Maria (opinion number: 5.698.140).

Jump Protocol and Equipment Setup

Squat Jump (SJ) and Countermovement Jump (CMJ) tests were used. The SJ consists of a jump from a squatting position, while the CMJ involves a jump after a rapid squat. Both followed the Bosco protocol, with three submaximal and three maximal attempts performed on an AMTI Force Plate.

The trial yielding the greatest jump height on the force plate was retained for analysis; the corresponding trial from the Actigraph® GT3X was used for the accelerometer-based calculation, ensuring that both devices were compared on the same jump. Simultaneously, an Actigraph® GT3X accelerometer was used, fixed to the participants' waists, as illustrated in Figure 1.

The device was positioned on the anterior surface of the trunk, aligned with the umbilical scar, and secured using the elastic belt provided by the manufacturer. The belt was fastened tightly to minimize movement artifacts during jumping. Raw acceleration data were exported from ActiLife software (ActiGraph, Pensacola, FL, USA) in CSV format at a sampling frequency of 100 Hz. The resultant acceleration signal was computed as the vector sum of the three axes (x, y, z) with gravitational acceleration subtracted, as described in the Data Analysis section. Takeoff and landing events were identified from the resultant acceleration curve as the interval during which the signal approximated zero, corresponding to the airborne phase with no ground contact. Force plate data were recorded and processed using the standard AMTI software with default parameters; takeoff and landing were defined by a vertical ground reaction force threshold of 10 N. No formal time synchronization was performed between the force plate and the accelerometer; jump height values obtained independently from each device were compared after processing. Accelerometer data were recorded with date, time, and jump validation for subsequent analysis.

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Figure 1. Illustrative image of accelerometer positioning.

Data Analysis

The inertial sensor measures acceleration in the x, y, and z axes. Its software enables report generation, including raw data (RAW) in CSV format. The complete processing workflow, from raw acceleration data to jump height estimation, was performed in Microsoft Excel 2016 and consisted of the following steps: (1) raw triaxial acceleration data (x, y, z axes) were exported from ActiLife software at 100 Hz in CSV format; (2) gravitational acceleration (g = 9.81 m/s²) was subtracted from the resultant signal to isolate the dynamic acceleration component; (3) vector summation was performed using the following equation 1:

$$af = (\left(\sqrt{x^2 + y^2 + z^2} - g\right) * 9.81)$$

Where, af = represents final acceleration, x, y, and z = are acceleration vector values in gravities (g), with g = as the constant acceleration of gravity (9.81 m/s²). From this final acceleration, force (in Newton = N) was calculated using basic dynamics formulas as shown in equation 2:

$$F = m * a$$

Where, m = represents the mass in kilograms, and a = is the acceleration in meters per second squared, followed by flight time measurement[11].

Force plate data were recorded and exported in text format (.txt). The platform measures force data in three axes, and vector summation was essential to determine final force. Based on the ground reaction force, flight time was calculated for subsequent jump height projection. Jump height was calculated using the formula proposed by Bosco, Luhtanen, and Komi (1983), which uses flight time (s)[8]. This study used the equation 3:

$$h = \frac{(g \times t^2)}{8}$$

Derived from classical kinematics, where h = is jump height, g = is the gravity constant, and t = is flight time. The simplified version is shown in equation 4:

$$h = 1.22625 \times t^2$$

All values were tabulated and calculated in Microsoft Excel 2016. Continuing the processing workflow: (4) the flight phase was identified as the interval during which the resultant acceleration signal remained at zero (gravity subtracted), indicating absence of ground contact; the number of samples within this interval was counted and multiplied by the sampling interval (0.01 s at 100 Hz) to yield flight time; (5) jump height was then calculated from flight time using equation 3 and 4.

Statistical analysis

After normality testing, Pearson correlation coefficients (r) were calculated[12] to evaluate the linear relationship between devices. Agreement between devices was calculated using the Bland-Altman test[13]. To evaluate the presence of systematic bias, a one-sample t-test was applied to the mean difference between devices (force plate minus accelerometer), testing whether the mean difference was significantly different from zero.

Intraclass Correlation Coefficients (ICC) between the force plate and the Actigraph® GT3X were also calculated. Specifically, ICC(A,1) two-way random effects model, absolute agreement, single measures, was used, as it is the most appropriate model for method comparison studies evaluating whether two instruments can be used interchangeably.

All statistical analyses were conducted using SPSS software (IBM Statistics 22), with a significance level set at α=0.05.

Results

Mean results and standard deviations for the SJ and the CMJ were organized into Table 1.

Table 1. Vertical jump test outcomes across different sports modalities using the two measurements.

	Force Plate		**Accelerometer**	
Squat Jump Height (m)	**Mean**	**Standard Deviations**	**Mean**	**Standard Deviations**
Track and field	0.335	0.098	0.333	0.099
Basketball	0.340	0.053	0.336	0.047
American football	0.335	0.065	0.327	0.062
Total	0.335	0.076	0.327	0.075
Countermovement Jump Height (m)				
Track and field	0.364	0.113	0.361	0.116
Basketball	0.349	0.051	0.346	0.052
American football	0.343	0.096	0.344	0.092
Total	0.355	0.090	0.354	0.089

Notes: m = meters.

In addition, r correlation coefficients between the force plate and the accelerometer showed strong linear relationships across all modalities and are detailed in **Table 2**.

Table 2. Linear relationship between the force plate and accelerometer during vertical jump tests.

Modality	**Squat Jump**	**Countermovement Jump**
	r	***r***
Track and field	0.990	0.997
Basketball	0.836	0.967
American football	0.961	0.991
Total	0.970	0.989

Notes: *r* = Pearson correlation coefficient.

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The scatter plots and Bland-Altman plots for the combined sample are presented in Figures 2 to 7. Bland-Altman analysis revealed a mean bias of 0.0076 m (95% limits of agreement: −0.0287 to 0.0438 m) for the SJ and 0.0012 m (95% limits of agreement: −0.0254 to 0.0277 m) for the CMJ when all modalities were combined. The one-sample t-test of the mean difference against zero indicated a statistically significant systematic bias for the SJ total (p = 0.011), suggesting that the Actigraph® GT3X slightly underestimates jump height relative to the force plate in that condition. No significant systematic bias was detected for the CMJ total (p = 0.579) or for any modality-specific comparison (all p > 0.05). Modality-specific analyses are provided in Supplementary Figures S1–S18, presented at the end of the manuscript.

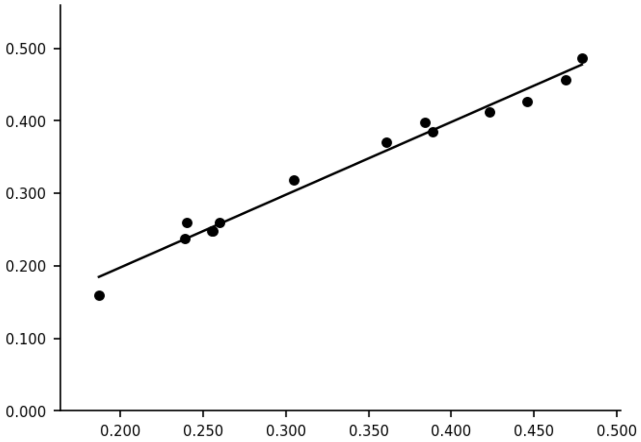

Figure 2. Scatter plot representing the Pearson correlation for the Squat Jump considering all modalities together.

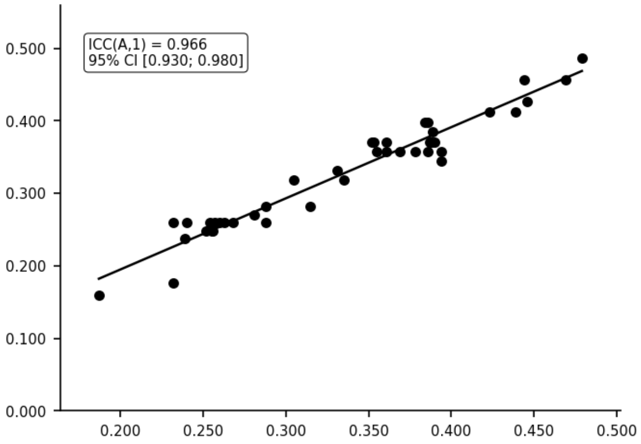

Figure 3. Scatter plot representing the ICC(A,1) concordance for the Squat Jump considering all modalities together.

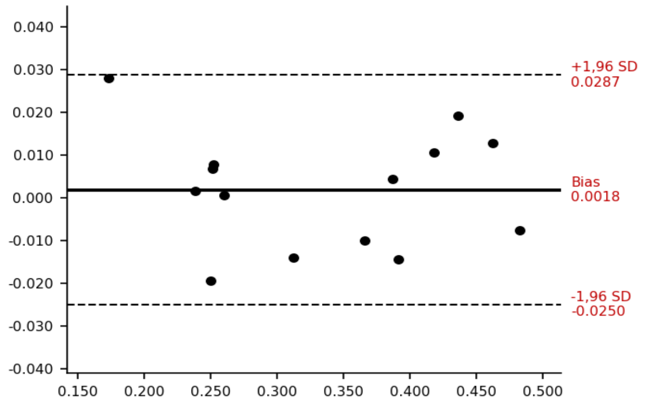

Figure 4. Bland-Altman agreement plot for the Squat Jump considering all modalities together.

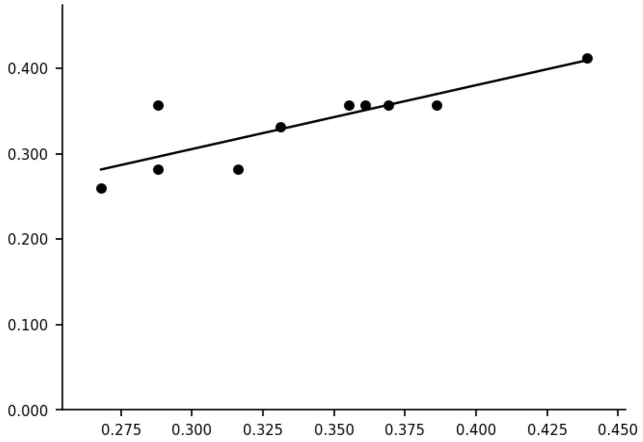

Figure 5. Scatter plot representing the Pearson correlation for the Countermovement Jump considering all modalities together.

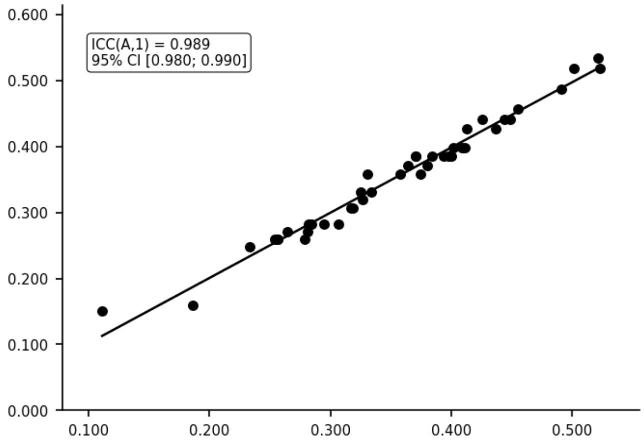

Figure 6. Scatter plot representing the ICC(A,1) concordance for the Countermovement Jump considering all modalities together.

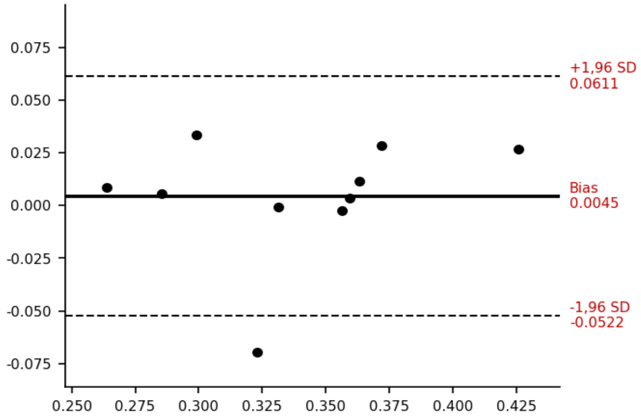

Figure 7. Bland-Altman agreement plot for the Countermovement Jump considering all modalities together.

The presence of systematic bias is organized in Table 3. The test indicated a statistically significant systematic bias for the SJ total, suggesting that the Actigraph® GT3X slightly underestimates jump height relative to the force plate in that condition. No significant systematic bias was detected for the CMJ total.

Table 3. Analysis of systematic bias between the measurement devices across sport modalities.

	Squat Jump	**Countermovement Jump**
Modality	*p*-value	*p*-value
Track and field	0.622	0.352
Basketball	0.638	0.423
American football	0.165	0.762
Total	0.011	0.579

Notes: Values represent the p-values derived from paired-sample t-tests.

ICC between the force plate and the Actigraph® GT3X showed strong agreement across all modalities and are detailed in Table 4.

Table 4. Inter-instrument reliability and absolute agreement for jump height estimations.

	Squat Jump	**Countermovement Jump**	
Modality	ICC (95% CI)	ICC (95% CI)	*p*-value
Track and field	0.991 (0.970; 1.000)	0.996 (0.990; 1.000)	< 0.001
Basketball	0.842 (0.490; 0.960)	0.968 (0.900; 0.990)	< 0.001
American football	0.957 (0.860; 0.990)	0.991 (0.970; 1.000)	< 0.001
Total	0.966 (0.930; 0.980)	0.989 (0.980; 0.990)	< 0.001

Notes: ICC (95% CI) = intraclass correlation coefficient (95% confidence interval).

Discussion

This study investigated the validity of the Actigraph® GT3X inertial sensor for measuring vertical jump height compared to a force plate, which is considered the gold standard. Statistical analysis revealed a high correlation between the two devices, with coefficients consistently above 0.870 across all athletic groups (track and field, basketball, American football) and both jump types (SJ and CMJ). Furthermore, strong agreement was observed through Bland-Altman analysis, with p-values greater than 0.05 in the T-tests for differences across all comparisons, indicating no statistically significant difference between the measurements obtained from the Actigraph® GT3X and the force plate.

These findings are consistent with previous research validating inertial sensors for jump height assessment. For instance, Gruber et al.[3] compared a Polar® watch, equipped with an integrated inertial sensor, against a force plate for measuring CMJ height. Their study also reported high correlation (r = 0.96) and agreement between the devices, with a mean error of approximately 5%. However, Gruber et al.[3] acknowledged limitations in their study, including a relatively small sample size (n=15) and the recruitment of healthy, non-athlete participants. In contrast, our study strengthens these findings by utilizing a larger and more diverse sample of 42 competitive athletes across different sports, enhancing the generalizability of our results to athletic populations.

Similarly, Camuncoli et al.[10] evaluated the validity of the Baiobit® inertial sensor for assessing vertical double- and single-leg countermovement jumps in athletes, comparing it with force plates and optoelectronic systems. While their study noted a tendency for the accelerometer to slightly overestimate jump height, they still reported good correlation and agreement, recommending its use in rehabilitation and sports settings. The minimal bias observed in our study with the Actigraph® GT3X further supports its reliability and accuracy, providing highly comparable results to the gold standard force plate.

The practical advantages of inertial sensors, such as the Actigraph® GT3X, are substantial. Their portability and significantly lower cost, compared to traditional force plates, make them invaluable tools for neuromuscular performance assessment. These devices offer unprecedented opportunities for monitoring athletes in remote environments, field settings, or in contexts with limited resources where force plates are impractical or inaccessible. This reinforces the emerging and critical role of wearable technology in sports science and rehabilitation, facilitating accessible, high-quality, and continuous assessments of athletic performance and recovery[3,5,10]. The ability to conduct frequent, non-invasive assessments in various environments can lead to more personalized training programs, better injury prevention strategies, and optimized return-to-sport protocols.

Strengths and limitations

A key strength of this study is the relatively large and heterogeneous sample of athletes across three distinct sport modalities, combined with a robust statistical approach (Pearson correlation, ICC, Bland-Altman analysis, and one-sample t-tests) benchmarked against the force plate gold standard. Limitations include the use of a convenience sample, the cross-sectional design, and the single accelerometer placement at the waist, which may limit the generalizability of the findings to other populations, devices, or body positions.

Conclusion

This study provides evidence for the validation of the Actigraph® inertial sensor for assessing vertical jump height. The device yields values very close to those obtained with a force plate. Its portability and low cost facilitate accessible field assessments and democratize high-quality monitoring. Future research should explore its applicability across a wider range of sports and its long-term consistency.

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Author Contributions

R.A.F.: conceptualization, data collection, data analysis, statistical analysis, and writing; N.C.T.: data collection and data analysis; R.R.B.: writing; D.L.S.: supervision, data analysis, statistical analysis, and writing.

Conflict of Interest

The authors declare no conflict of interest.

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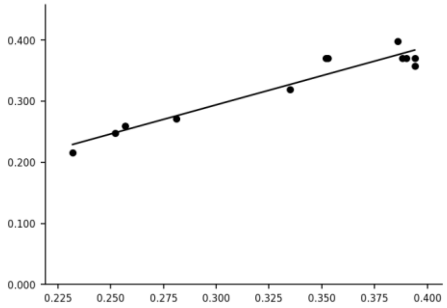
Declaration of generative AI and AI-assisted technologies in the writing process

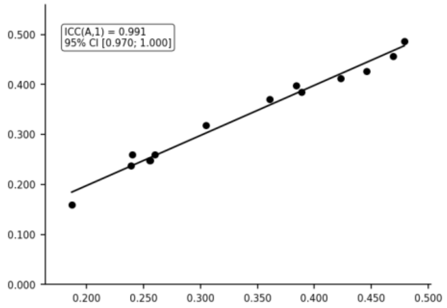
Artificial intelligence (Claude, Anthropic) was used solely for language editing and linguistic correction of the manuscript, after its full conception, analysis, and drafting by the authors. No generative AI tool was used for data generation, analysis, or interpretation of results. This use is declared in accordance with CNPq Ordinance No. 2,664/2026. The authors remain fully responsible for the final content of the manuscript and are solely responsible for the information included in this work.

Supplementary Material

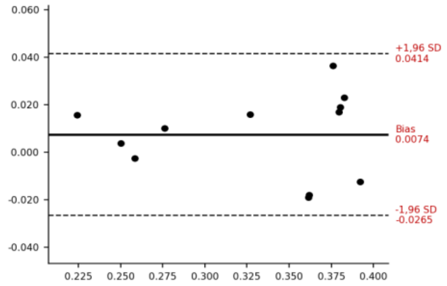
Modality-specific scatter plots and Bland-Altman agreement plots (Supplementary Figures S1–S18) are presented below.



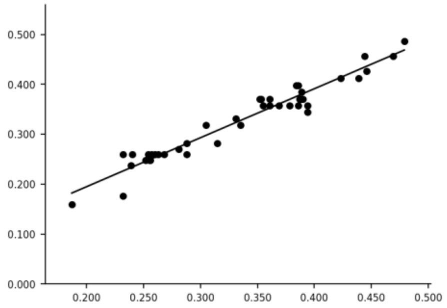
Supplementary Figure S1. Scatter plot representing the Pearson correlation for the Squat Jump in the track and field modality.



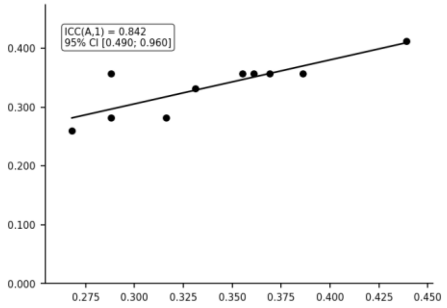
Supplementary Figure S2. Scatter plot representing the ICC(A,1) concordance for the Squat Jump in the track and field modality.



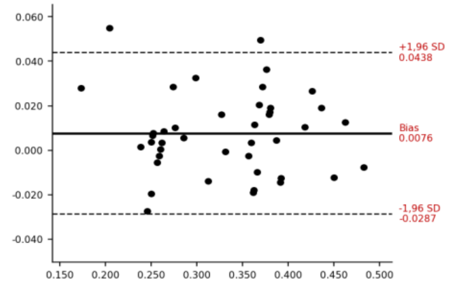
Supplementary Figure S3. Bland-Altman agreement plot for the Squat Jump in the track and field modality.



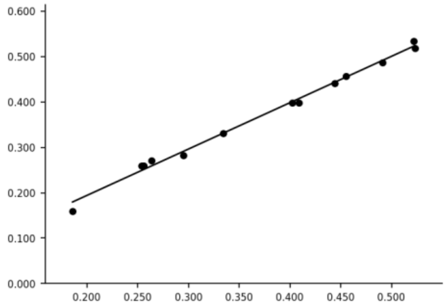
Supplementary Figure S4. Scatter plot representing the Pearson correlation for the Squat Jump in the basketball modality.



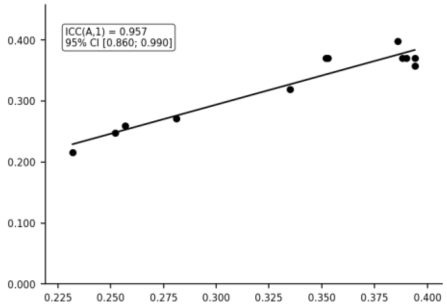
Supplementary Figure S5. Scatter plot representing the ICC(A,1) concordance for the Squat Jump in the basketball modality.



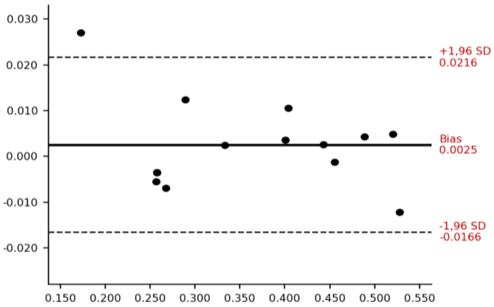
Supplementary Figure S6. Bland-Altman agreement plot for the Squat Jump in the basketball modality.



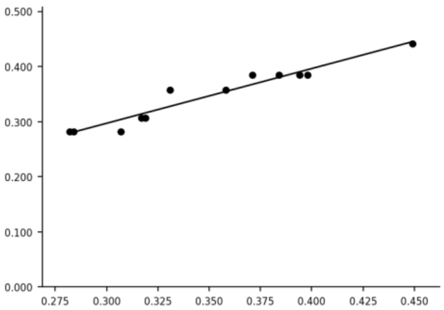
Supplementary Figure S7. Scatter plot representing the Pearson correlation for the Squat Jump in the football modality.



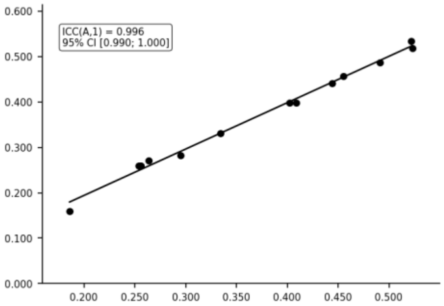
Supplementary Figure S8. Scatter plot representing the ICC(A,1) concordance for the Squat Jump in the football modality.



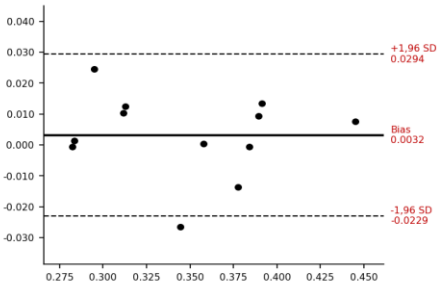
Supplementary Figure S9. Bland-Altman agreement plot for the Squat Jump in the football modality.



Supplementary Figure S10. Scatter plot representing the Pearson correlation for the Countermovement Jump in the track and field modality.



Supplementary Figure S11. Scatter plot representing the ICC(A,1) concordance for the Countermovement Jump in the track and field modality.



Supplementary Figure S12. Bland-Altman agreement plot for the Countermovement Jump in the track and field modality.

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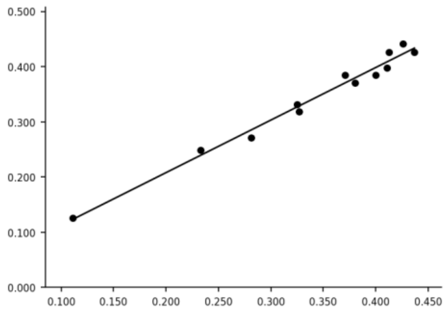
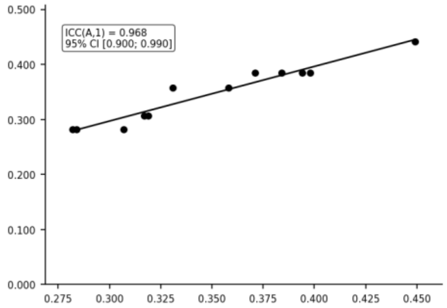
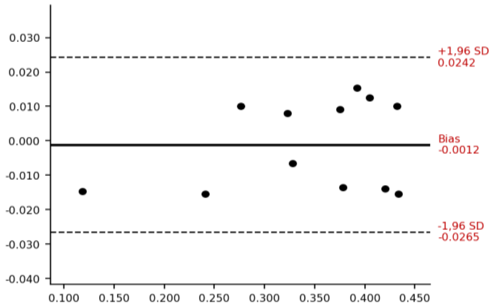


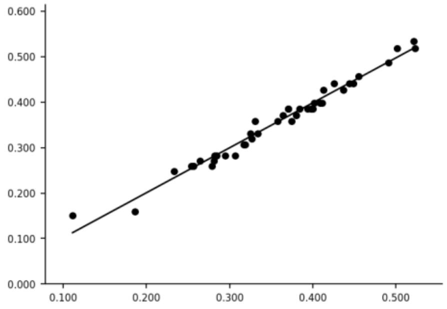
Supplementary Figure S13. Scatter plot representing the Pearson correlation for the Countermovement Jump in the basketball modality.



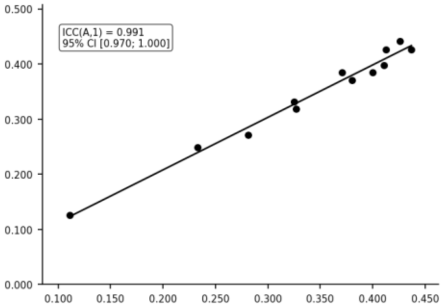
Supplementary Figure S14. Scatter plot representing the ICC(A,1) concordance for the Countermovement Jump in the basketball modality.



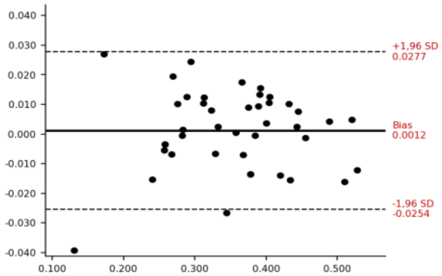
Supplementary Figure S15. Bland-Altman agreement plot for the Countermovement Jump in the basketball modality.



Supplementary Figure S16. Scatter plot representing the Pearson correlation for the Countermovement Jump in the football modality.



Supplementary Figure S17. Scatter plot representing the ICC(A,1) concordance for the Countermovement Jump in the football modality.



Supplementary Figure S18. Bland-Altman agreement plot for the Countermovement Jump in the football modality.